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RECORDS OF PULSE-RATES AFTER EXERCISES OF VARIOUS KINDS IN TRAINED AND UNTRAINED PEOPLE, ILLUSTRATED BY SPHYGMOGRAMS.

BY LIEUTENANT-COLONEL H. E. DEANE.

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THESE notes on pulse-rate after exercise are only contributory to a discussion, and exposition of facts on the part of others from which I hope to gain more information than I am able to impart. The subject is not merely of academic interest, but of great practical importance. I refrain from taking up time in particularising its practical application to military and civil surgeons and physicians, as I wish to confine myself now, as far as possible, to a record of observed facts. In a paper written in 1905 analysing the position of "attention," and dealing with the "irritable hearts of soldiers," I asked the question whether there should be such an increase of a recruit's pulse-rate at the end of his hour's gymnastic work as, for instance, from 96 to 144. I am now prepared to answer that question, at all events, for myself. Before passing on to the observations I have made, I wish to make some quotations from the latest text-book literature on the subject, an article by Clifford Allbutt in vol. vi. of his "System of Medicine," entitled, "Over-stress of the Heart" :—

(a) "On the whole the (pulse) acceleration is much more moderate in trained persons, and passes off sooner."

(b) Professor Allbutt quotes some experiments made by Dr. James Kerr on boys and girls, some untrained, others carefully trained for games; and then he says:—

"These observations of Dr. Kerr corroborate the conclusion of others that 172 is the extreme limit of pulse acceleration in the normal mechanism, and that 160 is rarely attained. If the limit of 170-172 be crossed, we have to do with an altered mechanism; perhaps with some affection of the medulla; perhaps with a shift of the cardiac rhythmical centre, and the condition may be called tachycardia. But to call mere frequency of pulse, under this limit 'tachycardia,' is either mere pedantry or falsely to suggest some new concept."

Personally, I should say that it was mere pedantry to describe a pulse-rate over 172 after exercise as tachycardia, and, any way, the use of the term in this connection does not at all agree with the definition of tachycardia given by Allbutt in another part of the volume.

(c) He quotes "Stahelin, who concluded that immediately after exertion the pulse-rate should fall about three beats per 10 seconds; but the fall is more rapid in the first 30 seconds than afterwards."

(d) Professor Allbutt says: "I think, indeed, for men in fair condition a doubled rate is excessive."

In order to answer my question about the recruit's pulse, I thought it would be helpful to know what was the pulse acceleration after more or less severe exercise of various kinds in persons trained to those exercises; and I wish here to define the sense in which I use the word trained. I do not mean a man who has undergone what is usually implied by a course of training for some specific event, as a boat race, or a boxing match, and who has lived on an exclusive or modified dietary, and, in short, made a distinct departure from his ordinary mode of life; but I mean men living under their ordinary and natural conditions, who are undergoing physical exertion every day, often twice a day, and sometimes three times a day for weeks, months and years on end; and who, in addition to their actual performances, have to be constantly practising so as to maintain, at the highest level, their suppleness and muscular co-ordination. To find such I have gone to the ranks of professional gymnasts and dancers, and have taken them exactly as I found them during their work. We read of all care possible being taken to avoid nervousness in making observations of this kind. Why? And if you know why, how are you going to do it? If any nervousness is a factor in the pulse acceleration, it should be taken into account, and how are you going to apportion the amount of the acceleration to nervousness and that due to physical exertion, and what is the difference in the action on the heart? How is it proposed, for instance, to eliminate any supposed element of nervousness in a body of recruits on their introduction to a gymnastic course? Or of a competitor in a championship race?

The only way to avoid misleading statements and opinions is to deal with the subjects of observation as you find them, and take all the presumed factors as a whole. My procedure has been to count the pulse before the exercise, and at the earliest possible moment after its cessation, either immediately after or

within a minute, as circumstances permitted. I avoid any attempt to draw up averages from a number of observations, as such averages are most misleading, and I give the details of some individual observations, selecting those which I think may be of greater interest and utility for the purpose of our discussion. I will relate, first, some observations on soldiers made at Aldershot in September, 1909, on teams training for the Duke of Connaught's Challenge Shield over an obstacle course, a distance of a little over a mile with eleven obstacles. I am only giving one man of a team, the first whose pulse I counted after the run; the other men on whom I made observations had time, of course, for the pulses to slow down.

A private in the Buffs team, who was doing the course for the first time, had pulse of 84 before starting and one at the rate of 180, counted for a quarter of a minute, when he finished. I counted three other men's pulses for a quarter of a minute, and recounted the first man's, which had dropped to a rate of 132. It was not practicable to make longer notes of these men.

A man of the Scottish Rifles team, who had been doing the course twice a day for a month, had a pulse of 76 on starting and of 148 on finishing, falling in a minute or two to 124.

In the next example I had an opportunity of seeing when the pulse reached its starting rate after the finish of the run.

A man of the Lincolns team, just beginning the course, started with a pulse of 72, but I do not know the rate on finishing, as I counted five others before his; and after that his was 104. In less than half an hour the team ran the course a second time, and this same man's rate was 88 on starting and 164 on finishing, falling in a very short time, while remaining standing, to 96.

The next instance is of a man at the Army Athletic Meeting at Aldershot in August, 1909.

Serjeant M., aged 24, of the Royal Irish Rifles, between seven and eight years' service, had a pulse-rate of 76 before running in the heat of the 100 yards race, which he won. Immediately after his pulse-rate for successive quarter minutes, with five seconds intervals was 180, 164, 148, 156, 124. He then had to go to get ready to compete in the long jump, and when he had finished that, about twenty minutes later, the rate was 136, which dropped to 120, and remained steady at that when he sat down. About two hours later his rate was steady at 100 when standing, and 92 when sitting. This was at 2 p.m. The same afternoon he ran in the final of the 100 yards, open to N.C.O.'s and men, and

won it; his pulse-rate immediately after the race was 172, but I was unable to keep him for longer observations. But I had another opportunity about one and a half hours later, after he had won the hurdle race, immediately after which his rate was 204.

I was unable to find out when the pulse resumed what may be called a normal quiet rate, but as he was going through the gymnastic course for instructor at the time, I had an opportunity of seeing him the following morning, when his pulse was steady at 60.

Now here was a man who had undergone training for those athletic feats, though whether combined with any dietary regimen I do not know, and it is unimportant, but it is a fair presumption to make that the greater part of time occupied in running the hurdle race his pulse was going steadily at the rate of about 200 per minute, and not only for a quarter minute as when I counted it immediately he stopped running.

I now pass to another line of life. A principal dancer at a pantomime had a pulse-rate of 80 when standing and sitting and 76 lying. Immediately after her dance of about two minutes the rate was 200; on sitting down it fell to 148; on lying down to 124; on again standing it was 104; sitting 92; lying 100. In about a quarter of an hour it was 88 standing and 82 sitting.

I repeated these observations a few days later. Before the dance the pulse-rate was, again, 80 standing, and immediately after the dance I kept her standing, and counted the pulse for quarter minutes, with five seconds interval, and the rate was 196, 164, 148, 132, 132, 120, 112, 108, 108, 108, 100, and steady at that, and remained so when she sat down; and on lying down the pulse fell to 84 after a short interval, and on again standing up was 100. Though a minute examination of the heart was not feasible, I was able to ascertain that the apex was beating in a well-defined area in its normal situation.

I show tracings of this lady's pulse before her dance; No. 1, with ordinary quiet respiration, and No. 2 showing respiratory effects; No. 3 after the dance, and No. 4 after a short interval, with respiratory effects. I shall be glad if some one will explain tracing No. 3, similar ones to which I give further on.

Next a troupe of four American step dancers, of whom I will only give two sets of observations. A man aged 32, had a pulse-rate of 88 before going on the stage, and on coming off the rate for the first quarter minute was 172, falling to 124 in two to three minutes; but during the performance this man also danced a solo,

which was done at a rapid rate, and one night he kindly left the stage immediately after it to enable me to count his pulse for half a minute; the rate for the first quarter minute was 200, and then after a few seconds interval 180. I made similar observations on one of the lady members of the troupe, whose pulse was 68 before going on the stage, immediately after a solo dance 188, falling quickly to 140, and when leaving the stage at the end of the performance 120, and about an hour and a half later 85.

Time will not permit of relating the observations on all the different performers, and I will now select cases which illustrate the time within which the pulse has quieted down after severe exertion, and while the people have been going about. I have been able to observe this by getting the performers on evenings when they have previously had a matinee performance.

In the case of what are known as whirlwind dancers, the man, at 9 o'clock before going on the stage, had a pulse-rate of 76, having performed at a matinee in the afternoon at 3.30 o'clock. Within a minute or two of leaving the stage the rate for the first quarter minute was 176, falling to 148 in a few seconds, and twenty minutes later it was steady at 104.

His lady partner in the performance at 9 o'clock in the evening had a rate of 84, having performed at a matinee at 3.30 o'clock. Immediately on leaving the stage her pulse-rate for the quarter minute was 216. This same lady on another evening had a rate of 80 before dancing, and immediately after one of 208, and half an hour later one of 108; and on another occasion she had a rate of 76 before dancing, of 212 after dancing, and half an hour later a rate of 108. Now, with the approximate constancy of pulse-rate before and after the performances it is fair to conclude that about the same frequency of pulse obtained during the matinee performances, and in about five hours the pulse-rates had resumed their normal under ordinary conditions of life. They may have resumed their normal rate sooner than that, but I can only speak definitely of the time at which I was able to make the observations.

Tracing No. 5 shows the lady's pulse before dancing, and Nos. 6, 7, 8, 9, after dancing, the tracings being taken successively. I may say I am only giving sections of the tracings, and not the whole lengths taken.

The next case is one which I was able to observe on two occasions with nearly a year's interval, during the whole of which period the lady had been at work. She is a well-known step-dancer and holds the reputation of being the Champion Sand

step-dancer, and is an expert of many years' standing. On the first occasion at 5 p.m., she had a pulse-rate of 76 while standing before dancing; she performed one dance only, and immediately after, her pulse-rate, counted for quarter minutes with five seconds intervals, was 156, 140, 120, 108, while standing; on sitting the rate was 112, 100, 96, 100, and after another minute and a half, 88. I saw her again the same evening at 11 p.m. when the rate was 76, and she had had dinner at 7 p.m., which as a rule she had at 3 o'clock. She performed three dances including a sand dance, and immediately after, the pulse-rate, counted in the same way as before was, while standing, 212, 160, 156, 132, 132, and on then sitting down, 120, 112, 112, 108, 104, 112, and remained steady at that for about five minutes when the observations ceased.

Nearly a year later I saw her again one day at 4.30 p.m. when her pulse-rate was 84 standing, and she had given a performance at 3 o'clock. On this occasion she danced a Scotch reel followed by a step dance, and immediately after, the pulse-rate was 146, 144, 144, 128, and on sitting 120, falling rapidly to 100. In this case the pulse quieted down to its normal level in about an hour, and the lady had to get from one theatre to another meantime. There was a marked agreement in the pulse conditions when observed on the two occasions with nearly a year's interval, and there is fair reason to suppose that very much the same conditions obtained constantly, so that for a period of years, daily and often more than once daily, the pulse-rate had not only been doubled but much more than doubled in rate, and that without any harm resulting.

I next take the case of a man, aged 38, who has been dancing since boyhood and has been specialising for the past thirteen years in what are known as Russian dances, in which a great deal of jumping and springing is brought into play. He may be seen at the present time at the Empire Theatre, though these observations were not made there, but at another theatre at which he was performing the same evenings as at the Empire. Before going on the stage his pulse rate was 68, and on leaving it, for quarter minutes with few seconds' intervals 164, 148, 148, 132, and in two to three minutes 104. During the performance of his troupe of dancers, this man danced a Russian solo, and on another occasion as he left the stage for a few moments I found his pulse rate for a quarter minute 180, and in less than half an hour after the performance it was steady at 96. I was unable to get longer observations as the troupe had to leave for the Empire. Here is a man who is a splendid specimen of activity, and who is

constantly practising, whose pulse is regularly much more than doubled in rate, which has probably been going on for some years. Tracing No. 10 was taken before the dancing; tracings Nos. 11, 12, 13, after the dancing.

I will now give a selection only of many observations made on a troupe of girls doing in their performance two dances with songs, and finishing with a skipping rope dance. The pulse was counted for successive quarter minutes until the rate became uniform for a whole minute. At the time the following observation was made the girls had been giving the same performance every night and on Saturdays twice a day for between four and five months. The pulse rate before going on the stage was 84 when standing. About a minute after the performance when sitting, the quarter minute rate was 184, 180, 132, 136, 128, 128, 120, 120, 116, when it remained uniform for a minute and a half and then counted for a whole minute, 109; four minutes later the rate was uniform at 104; a quarter of an hour later 104 when standing and 92 sitting. In most forms of exercise the exertion is intermittent, and the pulse undergoes periods of acceleration and relaxation, and to see what actually happened in such circumstances, I got this same girl a quarter of an hour after her stage performance when her pulse rate was uniform at 112, to do a few high kicks, immediately after which her pulse rate for the quarter minute was 160, falling in two minutes to 144, and a few minutes later to 108.

I have not always been able to find out what the pulse-rates have been later on after the performances, but I have some which show that the normal rate is resumed within an hour or two; for instance, one girl's pulse was 80 three-quarters of an hour after; another was 94; another was 76 an hour and a quarter afterwards; but further observations on that point are necessary. In showing some tracings of these ladies before and after their exertions, I take the opportunity of referring to a point connected with the respiration. There seems to be an idea among some that drawing voluntary deep breaths slows the pulse when quickened after exertion. I have not only not met such a case yet, but I have noticed that when the pulse is accelerated beyond a certain rate that the ordinary respiratory effects of alternate shortening and lengthening of the diastole are absent, which are present when deep breaths are drawn at a slower rate of the pulse. I am not prepared to say within 10 or 20 beats what the rate of pulse is below which such respiratory effects are noticeable, but I think that if the pulse-rate is much over 100 per minute the respiratory effects are absent.

When such respiratory effects are present they do not reduce the total pulse-rate. It must be remembered that these respiratory effects are more marked in some people than others.

In passing, I may say that I have tried to ascertain by taking successive tracings when and how the character of the tracings changes, but I cannot give any very satisfactory demonstrations; tracing No. 14 was taken immediately after a skipping-rope dance, No. 15 was the sixth successive tracing, and No. 16 was taken one and a half hours later. Tracing No. 17 was taken after a skipping-rope dance, with a pulse-rate of 116, and while voluntary deep breaths were being drawn; No. 18 was taken about an hour later, when the pulse-rate was 82, and the respiratory effects became marked. Tracing No. 19 was taken a short time after the dance, when the pulse-rate was 100; and No. 20 about an hour later, with the pulse-rate at 76, and the difference in the respiratory effects marked.

Lastly, the statement that the pulse acceleration is much more moderate and passes off sooner in trained than in untrained persons requires much qualification; and first of all the two classes are hardly comparable, because a man unused to any particular form of exercise cannot perform the work done by a man accustomed to it. I have not made so many observations on persons doing unaccustomed exercises, but those I have made do not in the least bear out the book statement quoted. The method I adopted was to get people to do, or attempt to do, something to which they were more or less unaccustomed. Now running upstairs is a trying form of exercise, and I got a porter, aged 42, an ex-soldier, to run up from the basement to the top of the theatre and down; his pulse on starting was 78 standing, and directly after the exercise in successive quarter minutes it was 112, 88, 72, 72, 76, 76, 72; he then sat down, and the rate was 79 counted for a full minute; and on standing again 87.

I got a stage hand, aged 37, to perform the unaccustomed exercise of simply jumping about the stage, in fact, to do as well as he could what is known in gymnastic language as "knees up." Though he had not much idea of "knees up" he made the attempt. He started with a pulse-rate standing and sitting of 66, and afterwards for successive quarter minutes the rate was 156, 124, 116, 88, 76, 72, 72, 72, 64, 60; he then sat down, and it was 66 counted a full minute, and on standing up again 79; one and a half hours later, after his dinner and when he had been bustling about, as he said, it was 106.

I experimented on the pathologist to my hospital, a man aged 42, who had practised no form of exercise the past few years. He skipped as hard as he could for one minute; before starting his pulse-rate was 77; afterwards in successive quarter minutes the rate was 172, 144, 128, 128, 132, 108, 104, 104, 92, 92, 84, 96, 84, 92, 92, 92, 92, 88, 88, 84, 88, remaining steady at that; then on sitting, the pulse counted for a full minute was 87; a minute or two later it was 84.

I also got one of the hospital residents, aged 30, and a man unaccustomed to exercise, to skip as well as he could for about one and a half minutes. Before starting his pulse-rate was 84, when he had just left the operating theatre; afterwards the rate for successive quarter minutes was 176, 148, 144, 144, 144, 132, 132, 128, 132, 128, 124, 120, 124, 108, 120, 116, 120, and remained at that; quarter of an hour later it was 108; one and a half hours later 91; at midnight, *i.e.*, about six hours later, 72; and the next morning at 8.30 o'clock it was 71.

In order to make a more exact comparison I got a trained and untrained person to do the same thing, to run up and down 142 steps. A, trained, started with a pulse rate of 63; on reaching the bottom of the steps the rate was 116, nearly doubled; the rate fell 20 beats in the first fifteen seconds; between that point and the end of five minutes it fell 21 beats to an uniform rate of 75; and at the end of an hour it was 75 standing and 71 sitting.

B, untrained, started with a rate of 83; after the exercise it was 160, nearly doubled; it fell 20 beats in the first fifteen seconds; between that point and the end of five minutes it fell 28 beats to 112, fell another 16 beats in the next five minutes, and at the end of half an hour was 103 standing and 91 sitting, so that in half an hour the trained and untrained pulses were both within 8 beats of their starting points.

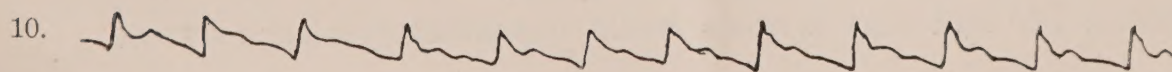
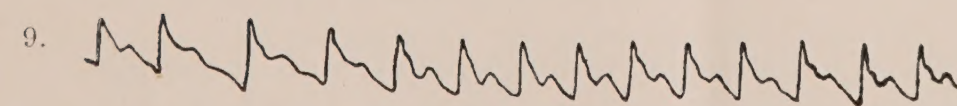
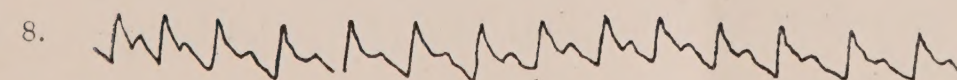
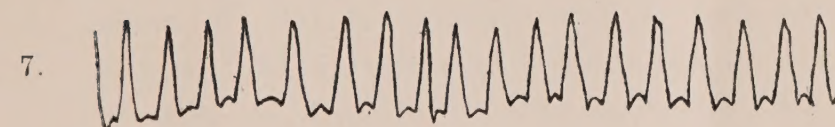
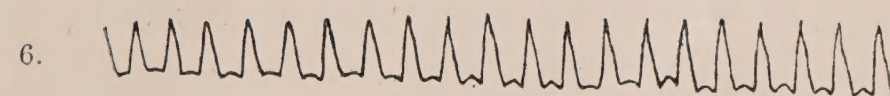
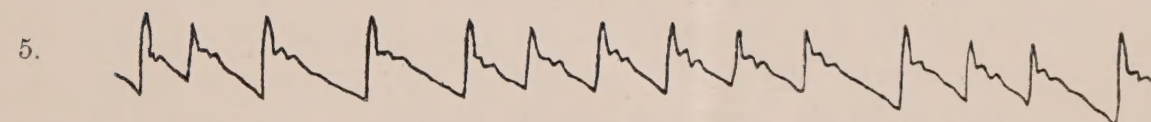
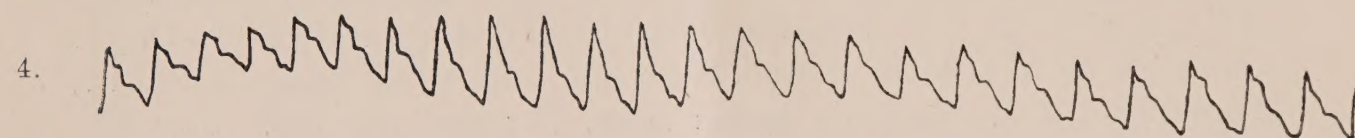
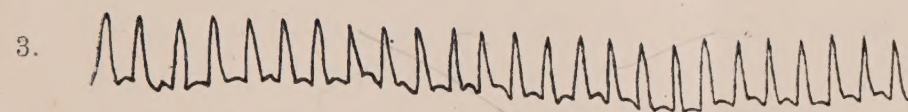
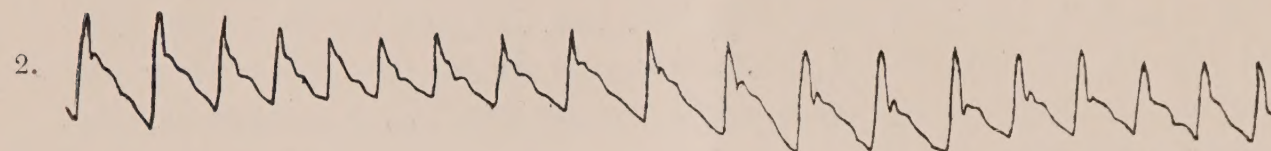
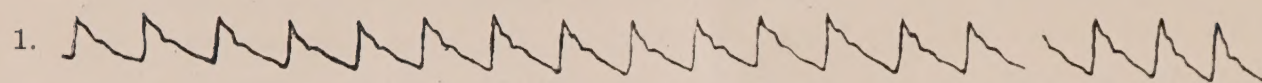
It would probably not be helpful now to multiply these examples, especially as there are others to follow me; so I will briefly summarise my observations.

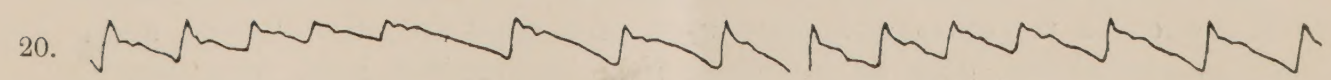
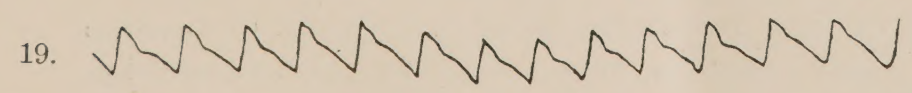
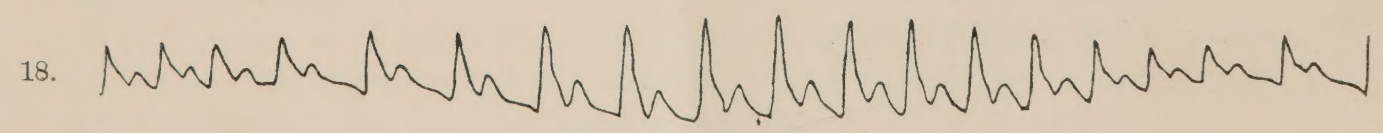
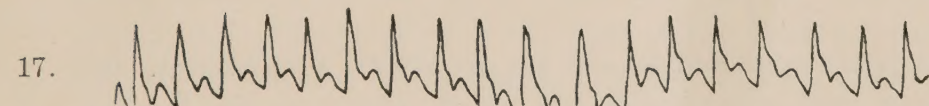
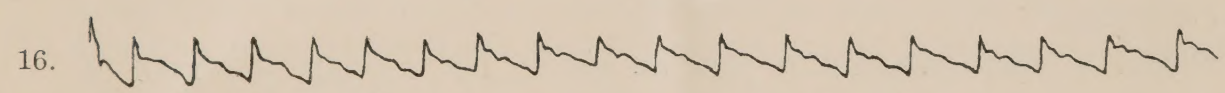
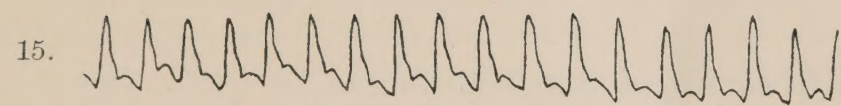
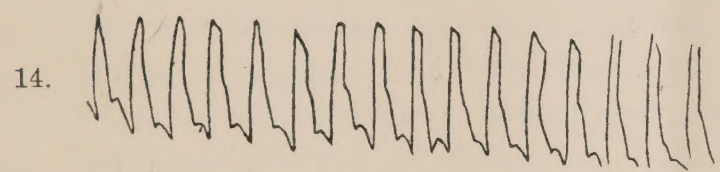
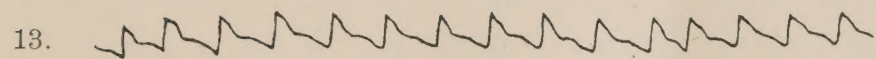
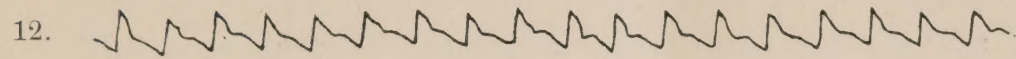
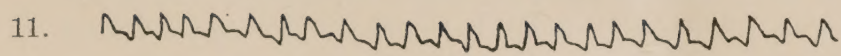
There seems to be nothing obvious in the rapidity of a man's pulse-rate after exercise to account in any way for the irritable heart of soldiers.

In people trained for a particular athletic event, and in people accustomed to perform regularly certain forms of exercises, the pulse-rate is usually doubled, frequently much more than doubled, and sometimes trebled within 40 or 50 beats.

A rate of 170 and over is quite usual immediately after exercise,

PULSE TRACINGS.





and so far from a rate of 160 being rare I have rarely found one under.

The exact time within half an hour or so that the pulse resumes the rate prior to the exercise I cannot definitely say, but I can say from the examples given in these notes that it does so within two or three hours; and no rule can be laid down that the pulse should be at any particular rate after exercise within any time measured by minutes or even half hours—I would go further and say that the criterion is the rate on the following morning. I do not know what the statement that the pulse decreases 3 beats every ten seconds means. If it means that as a rule the pulse decreases at that rate till the normal is resumed, then the statement is absolutely and entirely wrong. To refer again to two examples which are illustrative of what I have frequently found to occur; in consecutive fifteen seconds the rate decreased 32, 16, 16; then no decrease; 12, 8, 4; then no decrease; and then 4, remaining at that rate.

Again, a rate in periods of fifteen seconds decreased 24, 4, 16; no decrease for thirty seconds, 8, and then with periods of fifteen or thirty seconds with no decrease, it fell with a decrease of 4 to 8 beats.

When a pulse reaches a rate of about 100 to 112 the rate of decrease takes place by a fall of a few beats per minute, though I have found that it will remain at about 100 to 112 for half an hour or so.

Allowing for the incomparability of an exercise performed by a man accustomed and one unaccustomed to it, there is practically no difference in the behaviour of the pulse-rate, except perhaps the pulse of the man unaccustomed to it may not be so rapid and may settle down more quickly.

DISCUSSION.

Dr. MACKENZIE said: I recognise the importance of Colonel Deane's observations, for as yet we have no reliable standard by which to measure the heart's efficiency. Many observers have sought to find a standard of inefficiency in a certain acceleration of the heart's rate after exertion, but the results given to-night show that the inferences drawn from the rapid heart action after exercise are not nearly so simple as had been thought. It cannot be too strongly insisted upon that what are often looked upon as abnormalities, such as increased rate, diminished rate, irregularity, murmurs, are not necessarily signs of disease. Moreover, one of the most common forms of irregular action of the heart is not only not

a sign of heart disease, but its presence is probably an evidence that the heart is free from disease. I refer to that form of irregularity which I have called the "youthful form," or "sinus irregularity," where there is a constant variation in the duration of the diastolic period, usually due to, and associated with, the movements of respiration. This arrhythmia is caused by a varying action of the vagus nerve—the respiratory act stimulating this nerve. If there is an abnormal excitation of the heart muscle, as by fever or by some poison, such as occurs in rheumatic fever, then the vagus effect cannot be produced. In doubtful cases after a febrile illness, if this irregularity should appear, I have taken it as an evidence that the heart muscle has escaped. I call your attention to this matter as I find it of considerable importance in prognosis, and as yet my observations have been too few to enable me to speak with absolute certainty, and more extended observations are needed to enable us to decide whether this view is fundamentally sound.

In many healthy people, when the heart slows down after some violent exertion, it will be found to become irregular. The most common form of irregular action is this sinus irregularity of which I have just been speaking. Extra systoles, too, are not infrequent, and appear sometimes in perfectly healthy hearts. They are, however, very frequent in cases where the muscle wall is impaired, as in old rheumatic hearts, and in sclerotic and senile hearts. If the patient has been under such a drug as digitalis, partial heart block may occur, and pauses in the pulse may occur from the heart-block.

Lieutenant-Colonel MELVILLE said he had followed the paper with much interest, but at the same time he felt that his knowledge had not been much advanced by it as regards the cardiac condition of the soldier. The work done by the various dancers, &c., on whom Colonel Deane had made his observations, was of quite an abnormal nature, very severe, and lasting for a short time only. It did not seem to throw any valuable light on what occurred in a man doing comparatively slow but prolonged work, as in the case of the soldier on the march, or even during an attack. As far as his own experience went he was inclined to disagree diametrically with Colonel Deane, and he thought that careful training should lead to more rapid return of the heart to the normal rate.

Captain DUNBAR WALKER said that during a course of physical training, such as all recruits attend, which he was then going through at Chelsea Barracks, from personal observation of his own pulse, he had come to the conclusion that as the training proceeded there did appear to be a tendency for the pulse to return to its normal rate quicker. At the commencement of the training it usually took about four minutes to return to the normal rate. Now, after some thirteen attendances at the gymnasium, it took two minutes, and on some occasions no alteration in the rate between starting and finishing was observed.

Dr. PEMBREY remarked that such observations upon the pulse were

much needed, for the physician under the ordinary conditions of practice, dealt with sick, not with healthy men, and for this reason was liable to form wrong conclusions. The effect of exercise upon the pulse of healthy men was so great that within a minute its rate could be doubled; the means whereby this response was brought about were not well understood; there appeared to be two factors, a nervous and a chemical; the former enabled a man to respond rapidly, the latter acted more slowly, owing to its origin from the products of muscular activity, and maintained the adjustment of the work of the heart. The best test for the condition of the heart appeared to be the rate of recovery of the beat after short, vigorous exercise. Well-trained men showed a reduction in the rate, even within the first ten seconds of the cessation of the exercise.

Lieutenant-Colonel DEANE, in replying, thanked the members for their kind reception of his notes, and said he had not yet met a case (of the pulse settling down irregularly) such as that referred to by Dr. Moir, perhaps because his subjects were not young enough. The only irregularity, if such it can be called, was in the case of a man who presented extra systoles, which he had equally before the exercise, and about which the profession have learnt so much from Dr. James Mackenzie. He expected the criticism that those observations did not bear on soldiers' work, but they were carried out more with reference to the work in the gymnasium, and they had a distinct bearing in showing that there was no evil import in a recruit's pulse going up to 140 or over.

As regarded pulse counting, a stop watch was unnecessary, and a possible error of one or two beats in fifteen seconds was quite unimportant, and the same margin of error would occur with a stop watch with different observers. Dr. Pembrey had found the pulse of untrained people take longer to settle down after exercise, and of course his observations could not allow of exception being taken to them; equally the observations to the contrary related in the paper could not be taken exception to, and it showed that before any authority wrote in text-books on such a subject, it was important for him to make very much more extended observations than was often the case. For instance, to teach students that the normal mechanism of a heart did not allow of a pulse-rate over 170 after exercise was misleading. Dr. Pembrey supposed these performers had their chests constricted, an entirely erroneous supposition, because Colonel Deane knew, and could demonstrate that it was not so.
